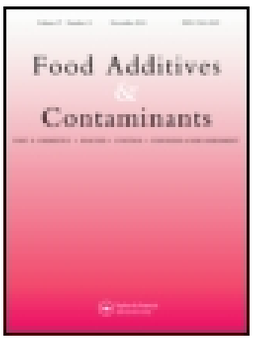

Food Additives & Contaminants: Part A

ISSN: 1944-0049 (Print) 1944-0057 (Online) Journal homepage: http://www.tandfonline.com/loi/tfac20

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To cite this article: Mauro Ferri, Loredana Baldi, Stefania Cavallo, Roberta Pellicanò & Gianfranco Brambilla (2017): Wild game consumption habits among Italian shooters: relevance for intakes of cadmium, perfluorooctanesulphonic acid, and ^{137}cesium as priority contaminants, Food Additives & Contaminants: Part A, DOI: 10.1080/19440049.2017.1293303

To link to this article: http://dx.doi.org/10.1080/19440049.2017.1293303

FOOD ADDITIVES & CONTAMINANTS: PART A, 2017
http://dx.doi.org/10.1080/19440049.2017.1293303

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Wild game consumption habits among Italian shooters: relevance for intakes of cadmium, perfluorooctanesulphonic acid, and ^{137}cesium as priority contaminants

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ABSTRACT

The consumption habits of 766 Italian shooters (96% males, 4% females), on average 52 years old, have been investigated, in Italy, through the distribution of questionnaires delivered during shooters' attendance to training and teaching courses, in compliance with 853/2004/EC Regulation provisions on food hygiene. The most consumed wild species recorded were pheasant > woodcock > choke among feathered animals, and wild boar > hare > roe deer among mammals, respectively. An average of 100–200 g game per serving (four servings per month) was consumed, with highest intakes of 3000 g per month; meat, liver, and heart were the preferred food items. Mammalian and feathered game was regularly consumed with friends and relatives in 83% and in 60% of cases, respectively. Accounting for an inventoried population of 751,876 shooters in Italy, it is estimated that there is regular consumption of wild game in around the 3% of the Italian population. More than 80% of responders were aware of health risks related to game handling and to food safety issues. Due to the occurrence in wild boar meat and liver of the heavy metal cadmium (Cd), the persistent organic pollutant perfluorooctan sulphonic acid (PFOS), and the radionuclide ^{137}cesium (^{137}Cs), it was possible to demonstrate the usefulness of such a food consumption database for intake assessment in this sensitive group of consumers. In high consumers of wild boar, threshold concentrations for intakes have been estimated in the ranges of 48–93 ng g^{-1} for Cd, 35–67 ng g^{-1} for PFOS and 0.20–0.34 Bq kg^{-1} for ^{137}Cs.

KEYWORDS

Italian shooters; wild game consumption; intake assessment; contaminants

Introduction

Wild game represents a valuable food source in shooters and their families, and in groups living on a subsistence economy and/or with a consolidated hunting tradition, such as in the case of bush meat consumption (King Furgal 2014). There is substantial qualitative and quantitative information available about the amounts of each food item produced, sold at retailer level, and consumed, from regular agriculture and animal farming practices, farmed game included, as consequence of the official checks to guarantee food safety (EFSA, 2013). However, there is sparse information about personal consumption and about the supply of small quantities of in-fur/in-feather carcasses to the final consumer and/or to local retailers, in agreement with the Regulation no. 853/2004 of the European Union. Within this frame, wild animals are not channelled through veterinary inspection. In the past, different papers considered setting up a dedicated survey on wild animal consumption to create a basis for a sound risk assessment with respect to lead contamination in meat and related human alimentary exposure. For example, in Switzerland, Haldimann et al. (2002) tried to correlate game consumption with lead intake; the Food Standards Agency in Scotland (FSAS, 2012) investigated habits and behaviours of high-level consumers of lead-shot wild game; in North Dakota (Iqbal et al. 2009), and in Norway (Metzer et al. 2013) significant associations have been proven between higher lead concentration in blood of hunters and their dietary habits based on wild game shot with lead-based ammunition. In Germany, Hoffman (2013) reported 13 kg per person per year as the average consumption of wild ungulates in hunter families. However, the hazards associated with personal wild game

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Supplemental data for this article can be accessed here.

consumption can also be extended from lead to bioaccumulative pollutants of priority relevance such as 'dioxin-like' compounds (Michigan Dept Community Health, 2004), and perfluorinated chemicals (Stahl et al. 2012), as a consequence of the overall environmental quality of rural and wild areas; in some places, selective advice to limit the consumption of certain food has been released by local authorities (McAuley & Knopper 2011) to prevent the available guidance values for chronic food toxicity being exceeded, such as those indicated by JEFCA for 'dioxin and dioxin-like' compounds (2002) (70 pgWHO-TE kg^{-1} bw $month^{-1}$ as provisional tolerable monthly intake; p-TMI), and by the US- EPA (2016) for the bioaccumulative, toxic, and persistent perfluorooctan sulphonic acid (PFOS) (20 ng kg^{-1} bw day^{-1} as reference dose; RfD). Lastly, there is the evidence-based epidemiological relevance of the presence of zoonotic agents, such as *Trichina* spp., *Mycobacterium bovis*, and pathogenic VTEC *Escherichia coli* in game for personal consumption (Díaz-Sánchez et al. 2013; Dragoi Nicorescu et al. 2015; Santos et al. 2015).

At the Italian national level, no specific survey about food habits in shooters has been carried out until now. In the national food consumption database (Leclercq et al. 2009), 40 of 3322 persons reported the consumption of game. In this database, the related food item category embraces also courtyard animal meat, does not differentiate wild from farmed game species, and also gives poor informative about the intake of wild game offal. Ramanzin et al. (2010) derived a mean and high consumption for the general population of 0.1–0.3 kg and of 1.0–4.0 kg per person per year of wild ungulate meat (from roe deer, red deer, fallow deer, chamois, mouflon, and wild boar), on the basis of ungulate harvesting in the last decade, and carcass weight. On local basis from the Viterbo province in Tuscany, Danieli et al. (2012) reported a mean consumption of meat and liver from wild boar by 118 shooters of 6027 g and 2646 g $year^{-1}$, respectively.

Thus, further to a previous study carried out on seafood consumption habits in the Mediterranean coastal population to prevent unacceptable methylmercury intakes (Dellatte et al. 2014), it also seemed worthy to further investigate wild game consumption at the national level with respect to feathered game and offal, in a sensitive group such as shooters, through the targeted delivery of a detailed questionnaire. This would represent the first step in carrying out a health based risk-oriented assessment with respect to a variety of hazards associated to wild game intended as a food resource. In this paper, we focused attention on the intake of three different contaminants, as representatives of inorganic, organic, and radioactive pollutants.

Materials and methods

Set-up of the questionnaire

A dedicated food consumption habits questionnaire has been developed on the basis of guidance for conducting fish and wildlife consumption surveys (US EPA, 1998), and validated by national experts, including the Italian Mammal Society and Italian Society of Fauna Eco-Pathology members, and by people in charge of the organisation of training and teaching courses to shooters at local levels. Under the provision of European Union Regulation no.853/2004/EC, to preserve certain hunting traditions without prejudicing food safety it is appropriate to provide for training for hunters who place wild game on the market for human consumption. The attendance to such courses should enable hunters to undertake an initial examination of wild game on the spot. The questionnaire was then administered to a selected group of already trained shooters enrolled as teachers in the above-mentioned courses (cooperative learning), to check for its readiness and easiness to be completed by untrained people.

The questionnaire, delivered to training shooters, after their agreement, was structured on 22 key questions selected as the most relevant, apart from the basic biographical outline (sex, age, residence, and place where the questionnaire was delivered). Briefly, the key questions were focused on: (a) the consumption of wild vs. farmed, mammalian vs. feathered game, local vs. marketed; (b) the seasonal frequency of the game-based servings consumed, and the averaged number on a monthly basis; (c) the number of game serving per month, and their average amount: less than 100 g, 100–200 g, 200–300 g, and if the servings were shared with family; (e) the most-consumed species; (f) the consumption of meat and/or offal, with related specifications; (g) the consumption of processed game meat; (h) the awareness about health risk in wild game manipulation; (i) the awareness about food safety risk; (j) the

awareness about and the attendance of training and teaching courses for shooters.

The questionnaires collected from different Italian regions (Figure 1) during the period September 2014–September 2015, were then inserted in the database, and the statistical analysis was performed with SPSS software (SPSS Srl, Bologna, Italy). Questionnaires with contradictory and/or incomplete indications, such as: (a) exclusive consumption of mammalian meat, and indication of feathered species as most consumed (or vice versa); or (b) lack of indication about the frequency of consumption and/or the amount of meat per serving, were eliminated. We administered the same questionnaire to 86 shooters on two separate occasions (at the beginning and at the end of the training course) according to the test-retest scheme. A reliability coefficient of 0.7 has been adopted as cut-off, where 1 indicates a perfect overlapping of the answers: the duplicate questionnaires not fulfilling such criteria were excluded. Game consumption figures have been calculated on positive responders (consumers) only. As the detailed amount (in grams) of each wild game species eaten was not reported in the questionnaire, whereas the total amount of feathered and of mammalian wild game per meal and the related meal frequency per week were known, we converted these indications in quantitative terms as follows: to the feathered group and mammalian group species ranked first, second, and third, a consumption figure of 60%, 30%, and 10% of the overall individual intake was given. The recovered consumption data have been subjected to the Kolmogorov–Smirnov test, to check for normal distribution.

Impact on food safety assessment

When accounting for the consumption of wild boar meat and liver, it seemed worthwhile to evaluate if the recorded occurrence of priority pollutants, such as the radionuclide ^{137}Cs, PFOS, and Cd would represent a risk of exceeding the toxicological guidance values for the intakes, accounting for the relative contribution of food of animal origin to the overall alimentary exposure. A default body weight of 72 kg was assumed for adult Italian hunters (98% male). The US-EPA RfD of 20 ng kg^{-1} bw day^{-1} and a relative contribution of 60% was assumed for PFOS (Klenow et al. 2013; US-EPA, 2016); occurrence data were derived from Brambilla et al. (2016). For ^{137}Cs, as a consequence of Chernobyl fallout on the Italian Alps in 1986, a dose of 0.2 mSv per person per year (equivalent to 15,835 Bq for ^{137}Cs) has been considered for food exposure, with a relative contribution of 20% (European Commission Regulation 770/90 1990); ^{137}Cs occurrence in boars from alpine region was derived from the Italian RESORAD 2012–2014 database. For cadmium (Cd), a tolerable weekly intake (TWI) of 2.5 µg kg^{-1} bw (EFSA 2009), a relative contribution of 20% from food of mammalian species

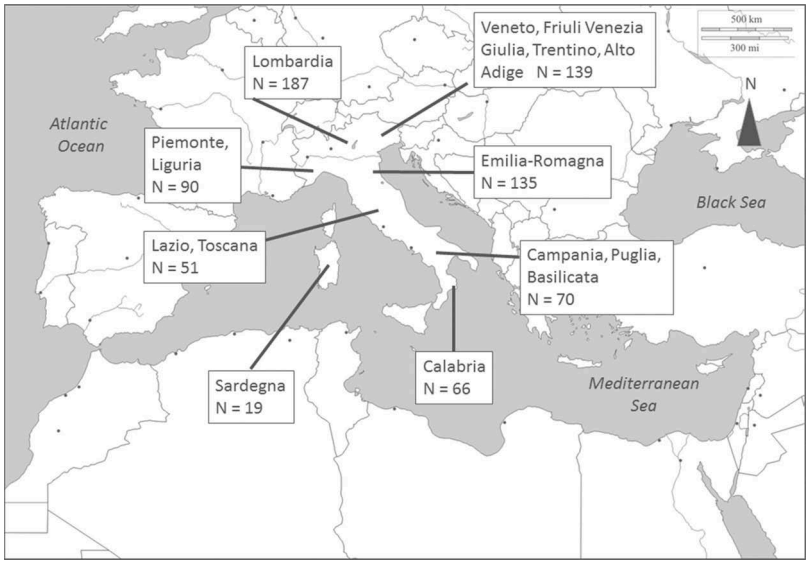

Figure 1. Provenance of the valid questionnaires (N = 766 as total) from the different regional districts of Italy, along with the related contribution to the total.

(EFSA 2012), and occurrence reported by Chiari et al. (2015) and Danieli et al. (2012) were used for computation.

Results

Of 834 questionnaires, 766 were fully accepted for the further statistical evaluation. The test-retest evaluation for reliability showed 78 out of 86 questionnaire scored above the cut-off of 0.7 (90%), with an overall median of 0.85: therefore, we were able to evaluate positively the overall quality of the answers. The geographical provenance of the respondent shooters (96% males, 4% females; 52 years old on average), is illustrated in Figure 1, while Figure 2 shows the reported most frequently consumed wild game species.

The statistical descriptors of the amount (g) of wild game meat consumed monthly are reported in Tables 1 and 2, according to the three most consumed species. The Kolmogorov–Smirnov test ($p < 0.05$) indicated a not-normal distribution for all the game food commodities considered. Offal from feathered game were rarely consumed, while liver and heart consumption from ungulates was indicated in 273 and in 169 out of 745 questionnaires, mainly referring to wild boars (Table 2; see Supplementary Material, Figure S1). In wild boar meat + liver consumers ($N = 181$) the average and P95 intake figures were computed at 420 and 1230 g per person per month, with a consumption ratio meat vs. liver of 1:1. The weight of meat and liver to the meat + liver intake was based on the ratio of the average concentration inventoried in meat and liver, that for Cd is 1:4, and for PFOS 1:30 due to the different (bio)accumulative behaviour of such chemicals. As a practical example, for PFOS the relative guidance value for intakes in a 72 kg bw shooter is 860 ng day^{-1}; in meat + liver consumers, around 28.8 ng PFOS comes from meat, while the remaining 835.2 ng PFOS from liver as a consequence of the 1:30 ratio in bioaccumulation. Such amounts have been divided for the average daily intake of 7 g (210 g/30 d = (meat vs. liver consumption ratio = 1:1), to recover the threshold PFOS concentration of 0.55 ng g^{-1} and of 15.9 ng g^{-1} in wild boar meat and liver, respectively. In the same way the threshold concentrations have been computed for P95 intakes and for Cd. Due to the substantial lack of occurrence data for ^{137}Cs in liver, the same mean value as for meat has been assumed.

The food habits records indicated that around 10% of shooters reporting wild game consumption also routinely eat farmed game (Supplementary Materials, Table 1S, 2S). The percentage of shooters sharing wild game with friends and relatives is shown in Figure 3, while the awareness with respect to health and food safety risks is reported in Figure 4. For further details on the associated consumption of different game species, see Figure 2S in the Supplementary Material.

The impacts of recorded consumption figures of meat and liver on the intake assessment of PFOS, Cd, and ^{137}Cs, are summarised in Table 3.

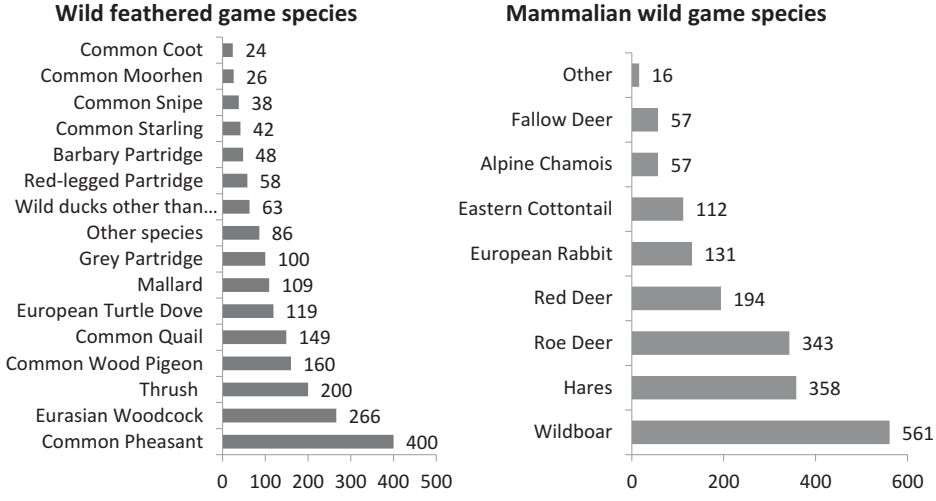

Figure 2. Most reported wild game species consumed among 766 Italian shooters.

Table 1. Statistical descriptors of the wild feathered game consumption (g per person per month) in 766 Italian shooters. Values referred to consumers only.

	Wild European woodcock meat	Wild common pheasant meat	Wild thrush meat
N			
Valid cases	225	300	180
Missing cases	41	100	20
Mean	125.9	156.7	169.1
Mode	50.00	50.00	50.00
Standard deviation	145.7	182.3	243.5
Mean square deviation	21,224.01	33,222.31	59,299.25
Minimum	15.00	15.00	15.00
Maximum	900.0	1050	1800
Percentiles			
25	42.26	50.00	50.00
50	75.00	96.88	75.00
75	150.0	176.8	170.2
90	300.0	300.0	427.4
95	411.7	600.0	663.3

Table 2. Statistical descriptors of the wild mammalian meat and of boar liver consumption (g person^{-1} month^{-1}) in 766 Italian shooters. Values referred to consumers only .

	Boar meat	Hare meat	Roe deer meat	Wild boar liver
N				
Valid cases	354	214	174	117
Missing cases	207	53	83	64
Mean	188.4	136.9	121.5	146.4
Mode	50.0	50.0	50.0	50.0
Standard deviation	249.4	147.4	141.0	160.1
Mean square deviation	62,225.1	21,722.0	19,891.4	25,639.7
Minimum	16.7	16.7	16.7	22.2
Maximum	3000	900	1000	1000
Percentiles				
25	60.0	50.0	50.0	50.0
50	100.0	90.0	75.0	100.0
75	200.0	150.0	150.0	187.5
90	450.0	300.0	250.0	300.0
95	750.0	462.5	381.3	387.5

Discussion

Questionnaire

The present dataset is based on 766 records from shooters located in northern, central, and southern Italy (Figure 1); with respect to the previous national wild ungulate consumption estimates from Ramanzin et al. (2010) based on culling records of ungulates, the gap of knowledge related to the unreported consumption of feathered game species, non-ungulate mammals such as hare, and wild game offal seems effectively covered. This can be considered an achievement, upon the availability of geo-referenced contamination data for the edible tissues of wild game (Chiari et al. 2015). On a qualitative basis, the three most reported feathered and mammalian species (Figure 2) are represented by wild game resident in the alpine, the continental, and the Mediterranean sub-regions of Italy. With respect to wild ungulates, Merli et al. (2016) reported an estimated kill of 892,000 wild boars (*Suus scrofa*), equivalent to an alimentary resource of 12,131 t; of 482,500 roe deer (*Capreolus capreolus*), equivalent to 1809 t; and of 91,600 red deer (*Cervus elaphus*), equivalent to 824 t. Such ranking results are in agreement with our survey in mammalian species (Figure 2), for the derived availability for consumption.

Wild game consumption

The consumption figures, referred to consumers only, show the mean is always higher than the

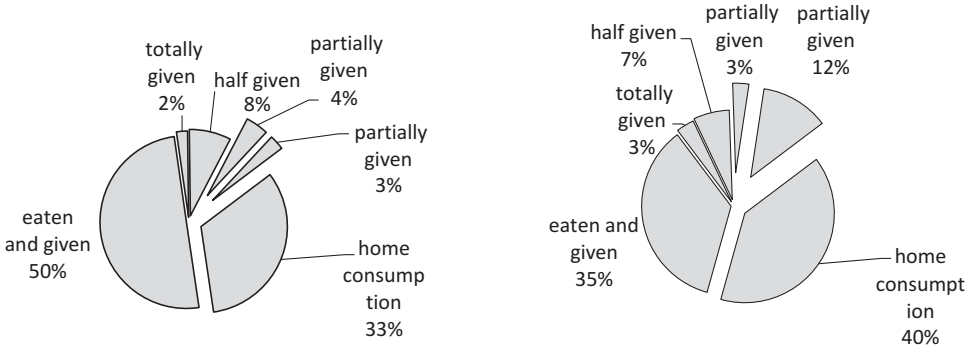

Figure 3. Family consumption of wild feathered game (left) and mammalians (right).

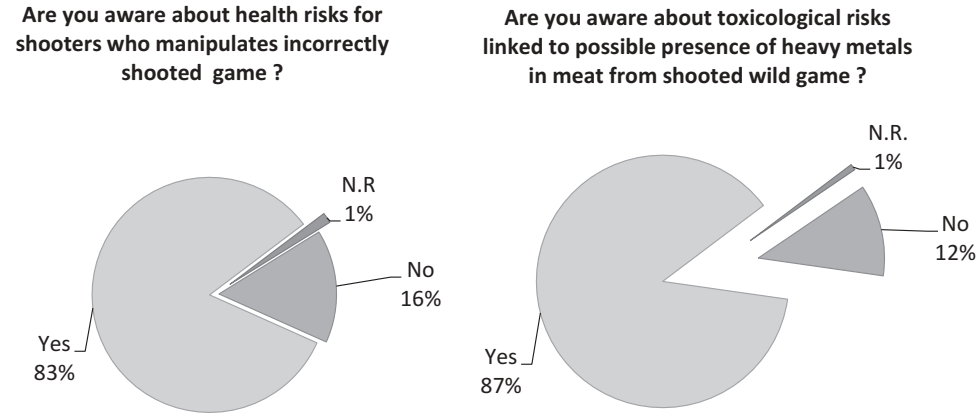

Figure 4. Awareness towards health risk from wild game manipulation (left) and food safety risks, with particular emphasis on heavy metals intake among Italian shooters. N.R. = non responders.

Table 3. Intake estimates in 72 kg bw Italian shooters of the selected contaminants, accounting for the inventoried average occurrence in Italian wild boars in meat (m) and liver (l): comparison with the relative guidance values (RGV) and calculation of the related threshold concentration (TC) on mean and P95 consumption figures of meat, liver (Table 2), and of meat + liver.

	Contaminants		
	Cd	PFOS	^{137}Cs
RGV	0.50 mg kg^{-1} bw week^{-1}	12.0 ng kg^{-1} bw day^{-1}	3,077 Bq per person per year
Mean occurrence g^{-1} fresh weight	20 ng (m); 84 ng (l);	3.04 ng (m); 94.0 ng (l)	0.023 Bq (m)
Mean intake	<0.01(m); 0.02 (l) mg kg^{-1} bw week^{-1}	0.27 (m); 6.37 (l): ng kg^{-1} bw day^{-1}	51.5 (m); Bq per person per year
P95 intake	0.03 (m); 0.06 (f) mg kg^{-1} bw week^{-1}	1.05 (m); 16.1 (l) ng kg^{-1} bw day^{-1}	205 (m) Bq per person per year
TC $_{mean}$ g^{-1} fresh weight	191 ng* (m); 246 ng* (l) 42.9 ng (m) + 129 ng (l)	138 ng* (m);177 ng* (l) 4.11 ng (m) + 119 ng (l)	1.362 Bq* (m) 0.608 Bq (m + l)
TC $_{P95}$ g^{-1} fresh weight	48.0 ng* (m); 92.9 ng* (l) 14.6 ng (m) + 43.9 ng (l)	34.6 ng *(m);66.9 ng *(l) 1.40 ng (m) + 40.7 ng (l)	0.342 Bq* (m) 0.208 Bq (m + l)

*Absolute values computed on meat (m) and liver (l) consumption, independently

median, represented by the 50th percentile value (Table 1, 2): this indicates a skewed distribution towards higher intakes, as already noted by Danieli et al. (2012) in their local food consumption survey in wild boar hunters. It is worth noting that on a quantitative basis, there is not a full correspondence with the qualitative data based on positive responders, as shown in Figure 2. Among feathered species, thrush is consumed more often than the common pheasant, and the European woodcock (169 vs. 157 vs. 126 g per person per month consumption). The reported highest intakes of these species are equivalent to 1800, 1050, and 900 g per person per month, respectively. Intake figures of farmed poultry fresh meat from consumers only from the Italian general population accounts for: 1314 g and 4914 g per person per month as average and the P99 intake computed on an adult of 60 kg body weight (Leclercq et al. 2009). Thus, the consumption of the three main feathered wild species may range from 9 to 12% of the average overall poultry meat intake, and can reach 36% of the poultry meat intake at the P99 value. Because feathered game consumption is often composed of different wild species (see Supplementary Material), it seems realistic that such combined feathered wild game intake may fall to around 35% of overall poultry consumption, in line with the computed high consumers figure.

Among wild mammals, the mean consumption for wild boar, hare, and roe deer meat accounts for 188, 137, and 122 g per person per month, respectively (Table 2). The average monthly wild boar intake of 188 g is lower than the 492 g computed by Danieli et al. (2012). The latter figure refers to local consumption from the Tuscany region, which has the highest wild boar hunting vocation, dating back to the Etruscans,

and is consistent with the P90 and P95 intakes of this survey (Table 2). The 188 g consumption represents about 17% of the 1116 g per person per month average fresh pig meat intake in the Italian adult general population – consumers only. This percentage increases to 77% when considering the maximum wild boar meat intake at 3000 g per person per month (Table 2) and the P99 fresh pig meat intake in Italian adults, consumers only (Leclercq et al. 2009). It is worth noting, as already done for feathered game, that the consumption of wild boar meat is often associated with that of liver, and with meat from other mammalian game species (see Supplementary Materials), thus indicating that the combined intake of wild mammalian species on average reasonably is higher than that for single species.

For hare and roe deer consumption, the national food consumption database does not allow appropriate comparison due to a lack of detail: under the 'other fresh meat' category (bovine, pork and poultry meat excluded), the mean intake in Italian adults – consumers only, ranges from an average of 1404 g to a P99 of 3546 g per person per month. Under this perspective, the mean hare or roe deer consumption of 147 and of 141 g per person per month may represent 10% of the overall intake within the other meat category, while for high consumers this percentage increases to 25% for hare and to 28% for roe deer, respectively.

Ramanzin et al. (2010) estimated an intake of 1.0–4.0 kg per person per year of wild ungulate meat in high consumers, on the basis of the recorded number of shooters in the different Italian regions and of the figures of wild game kills. In the case of wild boar consumption, on a yearly basis our estimates based on a food frequency questionnaire indicate an average intake of around 2.256 kg per shooter, up to a maximum of 36 kg. The differences can be partially ascribed to the different groups considered: Ramanzin et al. (2010) derived the intakes accounting for the general population of the shooters; in this paper, we computed the intake figures on the number of shooters reporting the intake of wild boar (consumer only). The approach followed in this paper seems more conservative, also bearing in mind the differences in the traditional hunting habits between the different Italian districts and the preferences to eat feathered game only (Figures 1 and 2).

In terms of health relevance, the safety risks associated with wild game consumption cannot be restricted only to the 751,876 Italian shooters of the 2007 census (ISPRA, 2009). According to this survey, the regular consumption of wild game is extended also to shooters' families, in 83% (feathered game) and 60% (mammalian game) of cases (Figure 3). Considering a shooter's family composed of three persons on average (shooter included), this would lead to an overall 1,650,000 and 2,000,000 persons engaged in mammalian and feathered wild game consumption, respectively. Such figures are roughly equivalent to 2.6–3.2% of the total Italian population, and highlight the potential relevance of a health-based risk assessment on the kinds of food not always considered during regular food safety monitoring by authorities. A risk mitigation factor is the awareness of shooters of health and food safety risks from wild game intake, with particular emphasis on heavy metals; over the 80% of the responders gave positive answers (Figure 4), thus indicating the efficacy of the training courses organised under the animal hygiene provisions of Regulation 853/2004/EC. On the other side, the administration of the questionnaire to such courses attending shooters represented a qualifying aspect, with respect to the reliability of the answers.

Impact on food safety assessment

A comprehensive intake assessment extended to ungulates other than wild boars and to feathered species would require a dedicated paper and should be supported by a consolidated contaminants occurrence database. However, it seemed worthwhile to highlight the impact of these food frequency results on the assessment of the food safety risks in a sensitive group such as Italian shooters. For this purpose, we considered three priority contaminants, PFOS, Cd, and ^{137}Cs, already reported to be of potential concern (EFSA 2009; Stahl et al. 2012; Steinhauser & Saey Paul 2016); wild boars have been chosen due to their high consumption and the availability of occurrence data of the indicated contaminants in liver and meat.

In the case of the bioaccumulative PFOS, high intakes of liver (P95) even in presence of average contamination may lead to the relevant relative guidance value being exceeded (16.1 vs. 12.0 ng kg^{-1} bw) (Table 3). The concomitant intake of meat would contribute only around 3% to an increase of exposure,

as a consequence of the differences in toxicokinetics between the two edible tissues. In the case of the contemporary consumption of meat and liver, the identified threshold contamination (TC) in liver for average and P95 intakes (119 and 40.7 ng g^{-1}) are close to or even lower than the mean occurrence value (94 ng g^{-1}), thus suggesting the opportunity to release targeted advice on responsible/reduced consumption of such offal. In the Italian general population meat and offal represent less than the 10% of the overall PFOS mean alimentary intake, estimated by Klenow et al. (2013) as 0.18–0.26 ng kg-1 bw day^{-1} for lowerbound/upperbound (LB/UB) cases.

The mean occurrence of the radionuclide ^{137}Cs in boars from Northern Italy (22.8 Bq kg^{-1}) would not represent a major health issue according to average intakes from this food consumption database; exceeding the dose would likely occur in high consumers, and/or at contamination above the threshold of 0.600 Bq kg^{-1}, under the scenario of a mean consumption of meat + liver. Such a threshold is currently considered as the legal limit in the European Union for placing the meat on the market and is consistent with our estimates, even if the computed TC for high consumers resulted in the range of 0.208–0.342 Bq kg^{-1}. It is worth noting that such a limit is cumulative with the ^{134}Cs isotope, which has a shorter half-life (t½ = 2.1 years) than that of ^{137}Cs (t½ = 30.1 years). However, the ^{134}Cs isotope contribution has been considered negligible in this assessment, under the assumption that the largest amounts of these radionuclides were released and deposited in the Italian Alpine environment as consequence of the Chernobyl nuclear accident, in April 1986. The baseline ^{137}Cs levels in bovine meat from routine monitoring at a regional level from northern Italy (Lombardia Region, see Figure 1) are reported in the range 0.1–1.0 Bq kg^{-1} in bovine meat and below the limit of determination of 0.1 Bq kg^{-1} in pork meat, as result of the different feeding habits (pasture and forage in cattle, industrial feed in pigs). Such values are around 20-fold lower than the mean contamination measured in wild boar meat (ARPAL, 2017). The relative ^{137}Cs intake from a daily consumption of 130 g carnivorous meat in adults would be equivalent to that from the average daily ingestion of 6.5 g of wild boar meat.

Cadmium is considered important as an emerging pollutant and has been considered in this paper because of its presence in large amounts in mushrooms and truffles, which represent the favourite food source of wild boars (EFSA 2009). From Table 3, even under the P95 consumption level, the computed intakes fall well below the RGV of 0.50 μg kg^{-1} bw $week^{-1}$, and can be exceeded under the worst case assumption only (highest intakes of meat and liver). In the Italian general population, EFSA (2012) reports a relative contribution of 7.5% in adults from bovine and pig meat and offal, with an estimated mean intake of 1.94–2.45 μg kg^{-1} bw $week^{-1}$ (LB/UB).

Uncertainties

There are some uncertainties in the wild game consumption estimates presented in this paper. Some regions are not represented in the database. This could represent a future opportunity to carry out a more comprehensive survey, with a stronger enrolment on a regional basis. The survey was limited to shot species, as these are rarely influenced by official controls, and information was lacking about their effective consumption by shooters. Animals subject to hunting by stalking have not been included in the present survey, because their meat is usually channelled through official inspection services, and then placed on the market at retailer level for consumption by the general population mainly as processed meat.

Conclusion

Through the regular activation of training and teaching courses for shooters, it has been possible to achieve valuable qualitative and quantitative information about wild game consumption. Our database, when matched with geo-referenced occurrence data of microbial and chemical hazards in meat and offal of shot animals, would help to give appropriate evidence-based advice for sensitive groups, thus enabling their empowerment and resilience, via open access to such information.

Acknowledgement

The authors wish to thank the following persons for their active involvement in the elaboration and administration of the questionnaire to Italian shooters: Davide Aldi, Elena Andreoli, Simone Angelucci, Elisa Armaroli, Guido Ballerio, Alessandra Barchetti, Marco Basso, Martina Besozzi, Giancarlo Bravaccini, Mario Burlin, Barbara Buttaboni, Mauro Caccia, Silvia Capasso, Francesco Casalinuovo, Pellegrino Cerino, Mario Chiari, Carlo Citterio, Gabriella Conedera, Ivano Confortini, Giuseppe

Cotturone, Umberto Di Nicola, Davide Fabbri, Gregorio Failla. Stefano Fenoglio, Sandro Flaim, Francesco Giofrè, Emanuela Gioia, Francesco Grenzi, Ruggero Giovannini, Maurizio Lodi, Dorotea Lombardo, Rosaria Lucchini, Luca Maffioli, Alessia Mariacher, Giuseppe Martino, Silvana Matiello, Vito Mazzarone, Luca Mattioli, Piergiuseppe Meneguz, Andrea Messori, Walter Mignone, Gioia Mingo, Federico Montanari, Federico Morandi, Carmelo Musarò, Giacomo Nicolucci, Loris Pasa, Francesco Peloso, Aurelio Perrone, Marco Picciati, Valerio Pituelli, Franco Recchia, Redazione URCA Informa ER, Maurizio Rozza, Silva Rubini, Arianna Schmoliner, Giampiero Semeraro, Stefano Tasca, Alberto Tazioli, Cecilia Testa, Karin Trevisiol, Cristina Troietto, Roberto Viganò, Luca Visconti, Ettore Zanon.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Italian Ministry of Health [grant RF 2009 number 1534860, Project ENVI-FOOD - coordinator Dr Gianfranco Brambilla].

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